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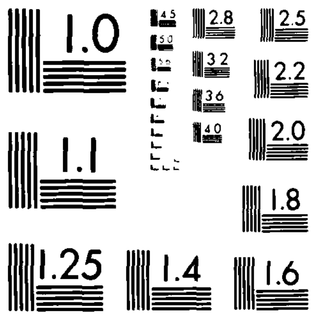
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SECURITY CLASSIFICATION OF THIS PAGE

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REPORT DOCUMENTATION PAGE

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1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: UNLIMITED. Approved for public release; distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S): AFOSR-TR- 86-0426
6a. NAME OF PERFORMING ORGANIZATION: University of Colorado / 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION: AFOSR
6c. ADDRESS (City, State and ZIP Code): Campus Box B-19, Boulder, CO 80309	7b. ADDRESS (City, State and ZIP Code): Building 410, Bolling AFB, DC 20332
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: AFOSR / 8b. OFFICE SYMBOL (If applicable): NP	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: AFOSR-85-0069
8c. ADDRESS (City, State and ZIP Code): AFOSR/NP, Bldg 410, Bolling AFB DC 20332-6448	10. SOURCE OF FUNDING NOS.

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT NO.
61102F	2301	A7	N/A

11. TITLE (Include Security Classification): Laser Diagnostic for Plasma Turbulence Research

12. PERSONAL AUTHOR(S): Scott Robertson and Raul Stern

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Yr., Mo., Day)	15. PAGE COUNT
Final	FROM 1/1/85 TO 12/31/85	3/21/85	3

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A tunable scanning dye laser pumped by an argon ion laser (Coherent Models 699-21 and INNOVA-12UV, respectively) has been installed for use as a diagnostic in experiments on ion beams and plasma turbulence. The laser passed acceptance tests in October 1985. Initial use is in a new experiment to determine the atomic processes in negative hydrogen ion sources. This project, entitled "Modern Diagnostics of Negative Hydrogen Plasmas," is supported by a NATO grant (#RG85/04321) and involves a collaboration of Prof. R.A. Stern (Colorado) and Dr. M. Bacal of the Ecole Polytechnique, Palaiseau, France.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: UC
22a. NAME OF RESPONSIBLE INDIVIDUAL: Scott H. Robertson	22b. TELEPHONE NUMBER (Include Area Code): 202/767-4906 / 22c. OFFICE SYMBOL: NP

DD FORM 1473, 83 APR   EDITION OF 1 JAN 73 IS OBSOLETE.

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SECURITY CLASSIFICATION OF THIS PAGE

AFOSR-TR-86-0426

Final Report for

AFOSR-85-0069

Laser Diagnostics for Plasma Turbulence Research

The purpose of the grant is to provide a tunable dye laser for diagnostic applications to experiments on plasma turbulence ion transport and ion beams. The primary piece of appartus purchased is a Coherent Model 699-21 scanning, single-frequency dye laser pumped by a 12 watt argon ion laser (Coherent INNOVA 12-UV). The laser was delived in June 1985 and passed acceptance tests in October 1985. The argon laser power was measured to be > 10 watts at 5145A and the dye laser power was measured to be 14 watts proadband and 1.1 watts, single-frequency. The scanning feature appears to operate smoothly except at wavelengths where the dye (Rhodamine 6G)has low gain.

The initial use of the laser facility is in connection with a joint research project sponsored by the Scientific Affairs Division of NATO, the North Atlantic Treaty Prganization. This is a collaborative plan intended to bring together leading expertise and facilities in two allied area: the hydrogen negative ion beam effort and plasma physics. The goals are:

1) to develop novel diagnostic techniques specifically adapted for measuring the essential properties of H^- and the plasmas in which H^- is formed b volume processes, and

2) to use these methods to characterize ion and electron temperatures, transport and local electric field values in volume— produced H^- sources.

The NATO project, entitled "Modern Diagnostics of Negative Hydrogen Plasmas," is directed by Prof. R.A. Stern of the University of Colorado [NATO #RG 85/0432] and involved collaborative research with Dr. M. Bacal of the Ecole Polytechnique, Palaiseau (Paris)France. The following sections describe the project and the function of the Colorado laser facility in this research.

The generation of intense H^- beams is a major effort of high current interest. A main technological use is the synthesis of neutral beams for plasma heating and inertial fusion, by merging positive with negative ion beams or by direct laser photodetachment of H^-. A most promising current approach is the volume generation process.[1] This occurs effectively in large-volume gas-discharge plasmas, to which extraction fields are applied by means of biased grids.

At the present stage, accurate characterization of the properties of these plasmas is needed: the densities and temperatures of ions and electrons, their transport as well as the local values of the fields in the plasma must be measured. This information is essential to the understanding of the processes involved, and to the optimization of the extraction function. Such measurements must be carried out without perturbing the processes, a nd with high resolution. The requires the development of a new generation of diagnostic techniques.[2]

The detailed characterization of particle and field properties in plasmas has evolved rapidly in recent years, in great part through the use of laser techniques.[3] Many of these are based on resonance flurescence, and are therefore not directly applicable to H^-. However, adaptations and extension of modern plasma diagnostics are possible. We propose to exploit current advances and apply them to the H^- configuration. Two specific examples are described below.

1. To characterize ion properties directly we propose to use variants of the "optical tagging" technique,[3] recently developed by us. These are two-point, two-time methods using two or more laser beams separted in space and time. Each beam photodetaches H^- locally, generating an electron current proportional to the H^- density. However, thermal motions and transport processes link the densities of H^- at the two points; thus changes in the electron current signal which occur in coincidence with the <u>two</u> laser pulses provide a measure of ion velocities at the kinetic scale.

These methods have been demonstrated on other plasmas,[3] and are currently being further developed in our laboratories. They can yield, with great space and time resolution, a complete description not just of ion densities and temperatures, but of the Boltzmann velocity distrbution function, which underlies the macroscopic properties of the ions.

2. To evaluate field strengths and directions within the plasma, we propose to make use of newly developed high resolution electron velocity distribution analyzers.[4] Using these, we will unfold the details of the electron current released by photodetachment pulse (this information is currently thrown away, since present techniques measure only the integrated electron current). The electron distribution function is highly sensitive to local electric fields, and can be used to deduce field magnitudes and directions.

The laser facility will be used for the central diagnostic of atomic states generated in the photodetachment of H^-. That is, the excited hydrogen atom resulting from the splitting of H^- into a free electron and a hydrogen atom carries a signature characteristic of a)the initial velocity of the H^- ion, and b) the final velocity of the free photoelectron. Using Laser-Induced Fluorescence[3], e.g. by scanning the narrow-band laser radiation across the

spectrum of Balmer lines, we can obtain the local temperature and drift velocity of the hydrogen atoms, and distinguish them from the background atoms whose properties are not affected by the photodetachment laser pulse. This information, combined with the transport measurements and electron energy analysis, completes the characterization of the volume generation and extraction process.

These and other novel techniques will be brought to bear on H^- ion plasma in the presence of extraction fields. The sequence of the research program will be first, to construct a test bench facility in which H^- is generated by the volume process, and in which the diagnostics can be introduced and tested. Following this, the best suited methods will be introduced into actual devices in which H^- generation process and extraction are optimized. The interaction between these two operations should produce high benefits to both the H^- and the plasma diagnostics communities.

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